ESS at the Test Bench

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Projector off. With that title, I intended to talk about identifying and repairing intermittents at the test bench.

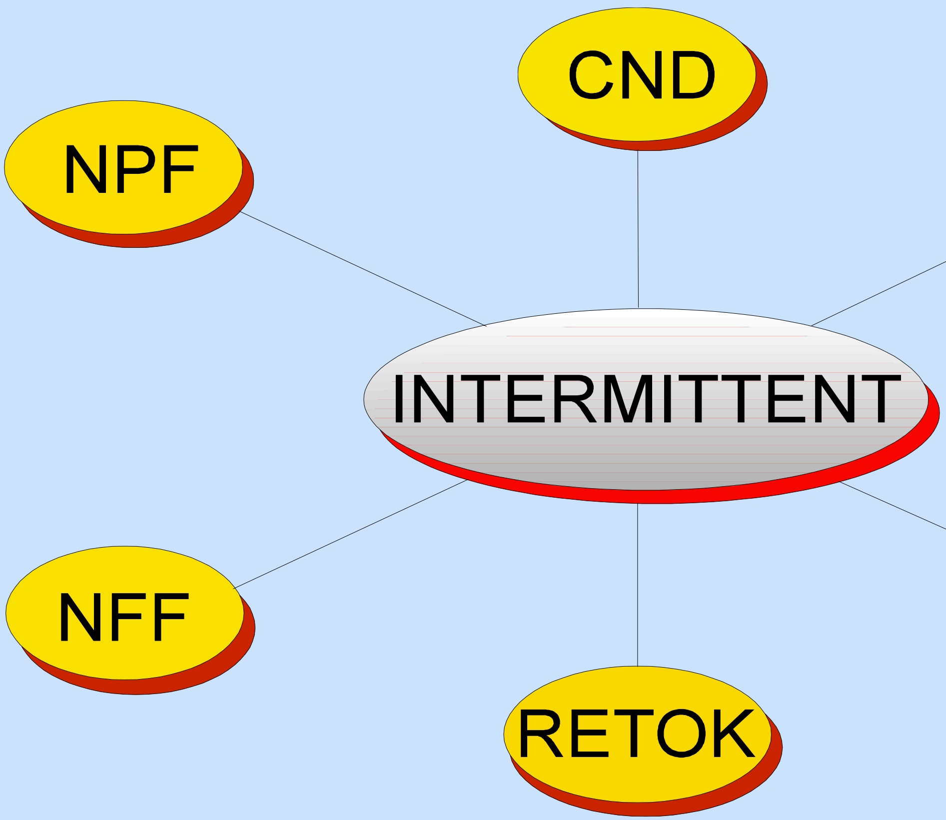
But then I learned that an equal number of intermittents exist in the vehicle's wiring. So I asked permission to broaden our discussion to include on-board investigation of intermittents. Is that OK with you?

When something has completely ceased to function correctly ("fail" is a politically dangerous word), we know how to repair or replace it.

We have much greater difficulty with intermittents, particularly cables or equipments that seem OK, but that have been reported faulty. Projector on. Figure 1. Do you recognize some of these tags?

Figure 1

TAGS

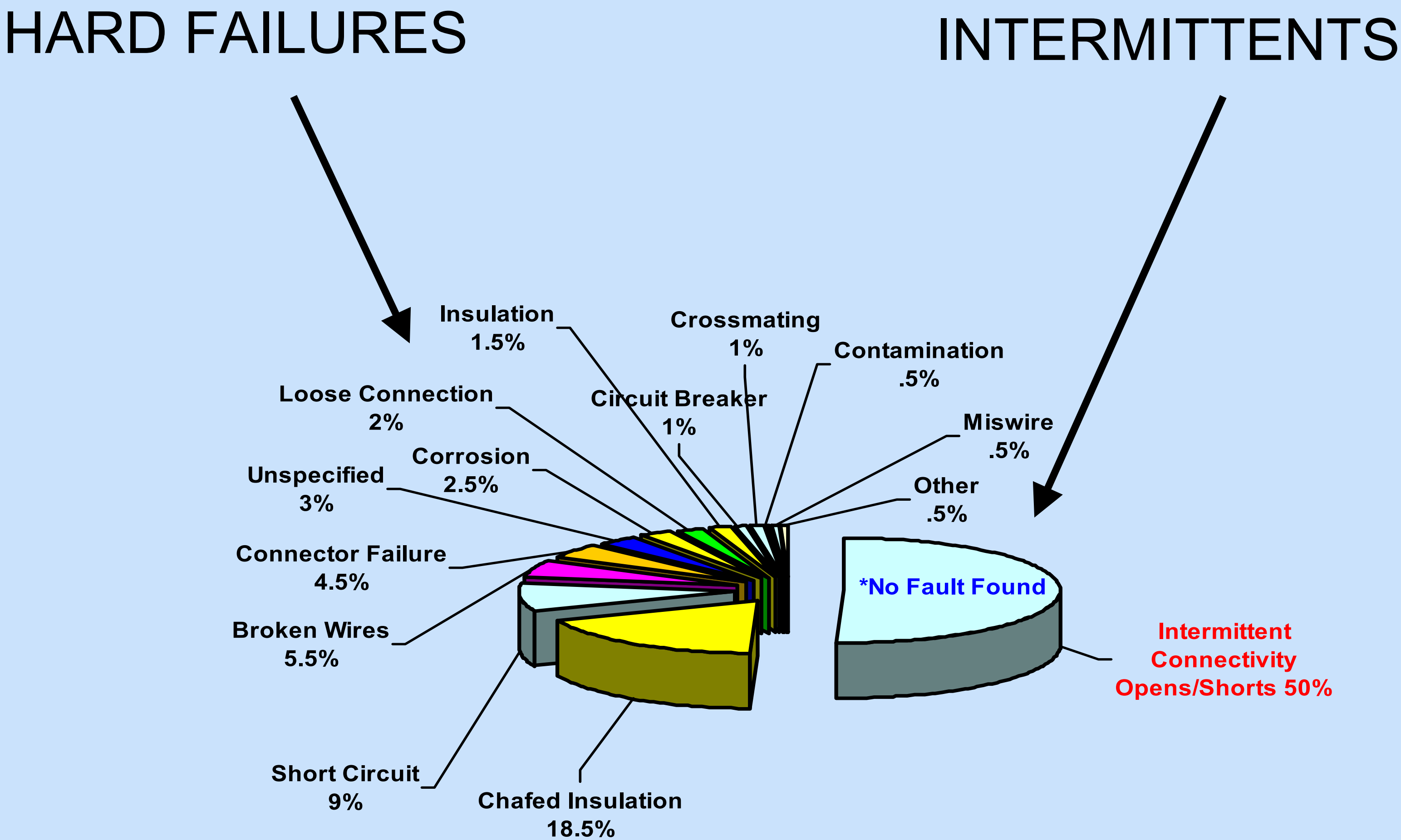


courtesy Universal Synaptics Corporation

Projector off. There are only two kinds of electronic failures: hard failures and intermittent failures. Hard failures show “bad” every time checked. All others are intermittents. Projector on, Figure 2.

We’ve surveyed hard failures and have lots of data on the causes. They may total half the failures.   It’s “other half”, the intermittents, that I hope we can expeditiously identify so we can repair or replace some hardware.

Figure 2



courtesy Universal Synaptics Corporation

Projector off. Unfortunately, no test or diagnostic procedure can detect and isolate a random intermittent problem unless it happens to occur at the exact instant it is being measured or tested. And that is VERY unlikely.   ATE, ICT and Continuity tests have little value for intermittents, because they don't continually monitor behaviors.

What <u>would</u> "do the job"? While preparing for this meeting, I happened to hear about some ex-Hill AFB folks out in Utah who have developed [projector on, Figure 3] a 256-channel analog continuous monitoring scheme.

Figure 3

IFD unit

courtesy Universal Synaptics

Here is a possible scenario. You have a vehicle on which a system has been reported "bad". Run a cable from an IFD or Intermittent Fault Detector into your power-off aircraft, ship or land vehicle. See http://www.usynaptics.com/hookup.htm.

Projector off. Here is what you do.

Disconnect a cable from a "black box" or display unit that is part of the suspect on-board system. Connect the IFD cable to the disconnected cable and continuously "evaluate north" on all the wires for up to an hour. If intermittents are logged, do something about those wires in that cable. If nothing logged, connect instead to the black box LRU and continuously "evaluate south" on all the pins for up to an hour. If intermittents are logged, suspect the LRU box. If possible, stay connected while you wiggle individual plug-in cards to verify they are properly seated or if they have a connectivity problem with the back plane. If wiggling one card creates much noise, pull that card and clean card and back plane connectors. If none creates noise, reconnect the original cable, disconnect another cable and repeat the foregoing. If all indications point to the LRU black box, remove it and send it to a repair depot, along with a printout of the IFD reports.

Those periods of evaluating vehicle wiring and the various black boxes can be made more effective if you can stimulate some or all of the vehicle wiring and the black boxes by varying temperature and locally "thumping" the structure. Possibly a "theater type" seat "thumper".

Projector on, Figures 4 and 5.

http://www.usynaptics.com/hookup.htm

Figure 4 Black box

courtesy Universal Synaptics

Figure 5

IFD unit

Projector off. OK, now. That equipment, pulled from an aircraft, a ship or a land vehicle, has reached your bench. [Now I'm back to my original plan for today's discussion.] But you find nothing wrong. It seems OK.

Do you tag it

NFW or NFF or NTF and send it back?

Won't it probably fail again in service, likely placing another mission in jeopardy, again be written up, and come again to your depot?

Let's break up that cycle.

From what I’m told, your present methods of finding intermittents are not working very well.

So please be willing to consider some new methods, such as that IFD scheme, even methods that differ from the methods mandated by contractor firms that built the hardware.

Within that equipment, some intermittent condition exists. Let's find the difficulty and (hopefully) fix the equipment and THEN send it back.

But how can we precipitate that flaw, that defect? How can we make it visible?

Some stress that exists in the field environment caused the reported problem in the field. Likely candidate stresses are

(1) thermal expansion/contraction due to temperature change and

(2) vibration.

Is there any way in which we can bring thermal stresses and random vibration (to be explained in a moment) to the test bench?

Projector on, Figure 6.   You can visualize portable ΔT.

Can you visualize a portable vibrator inside that shiny box on the left? Figure 7 does not show a real LRU. That was part of the vibrator development.

Figure 6 Portable Stress Chamber, *circa* 1980

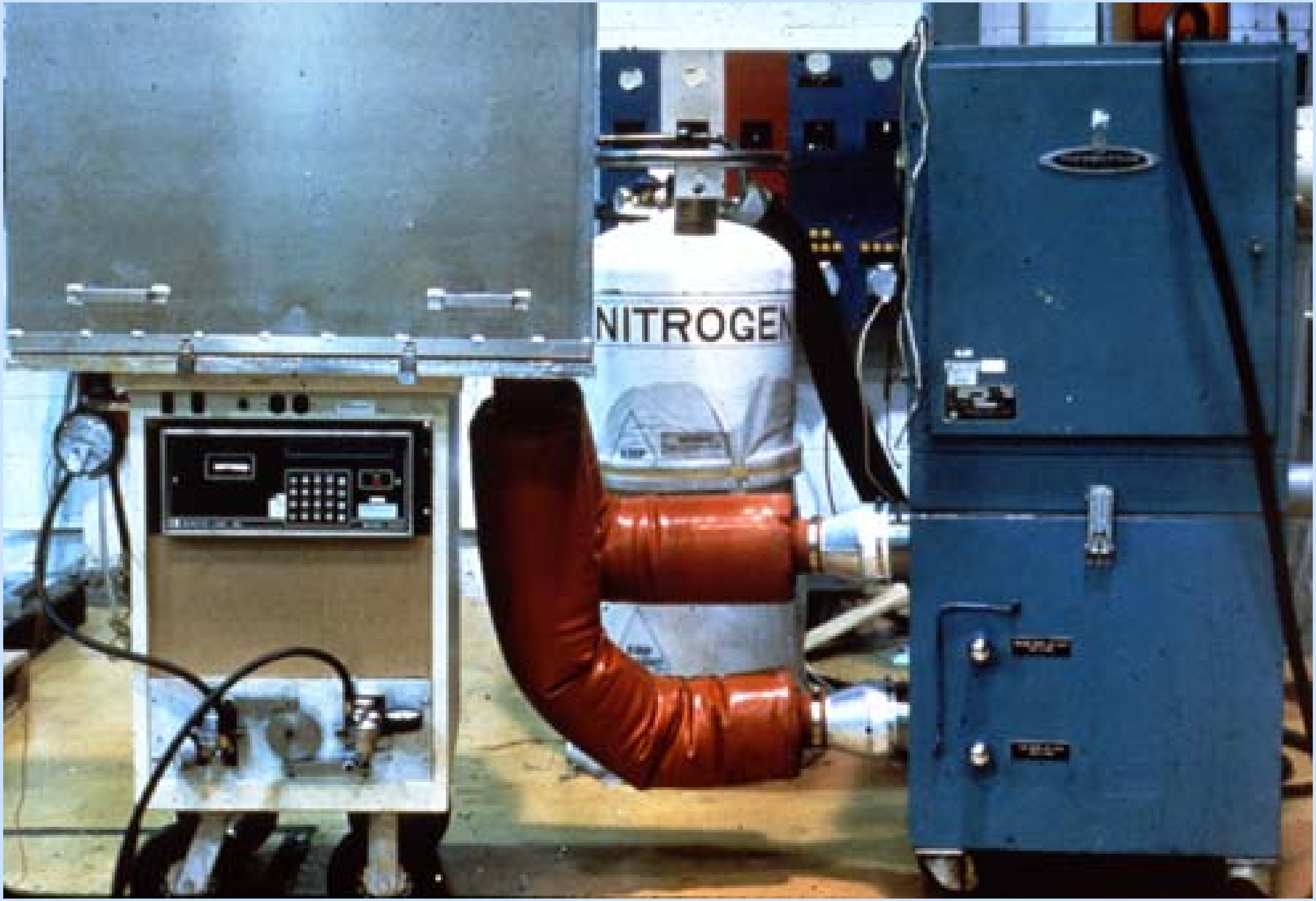
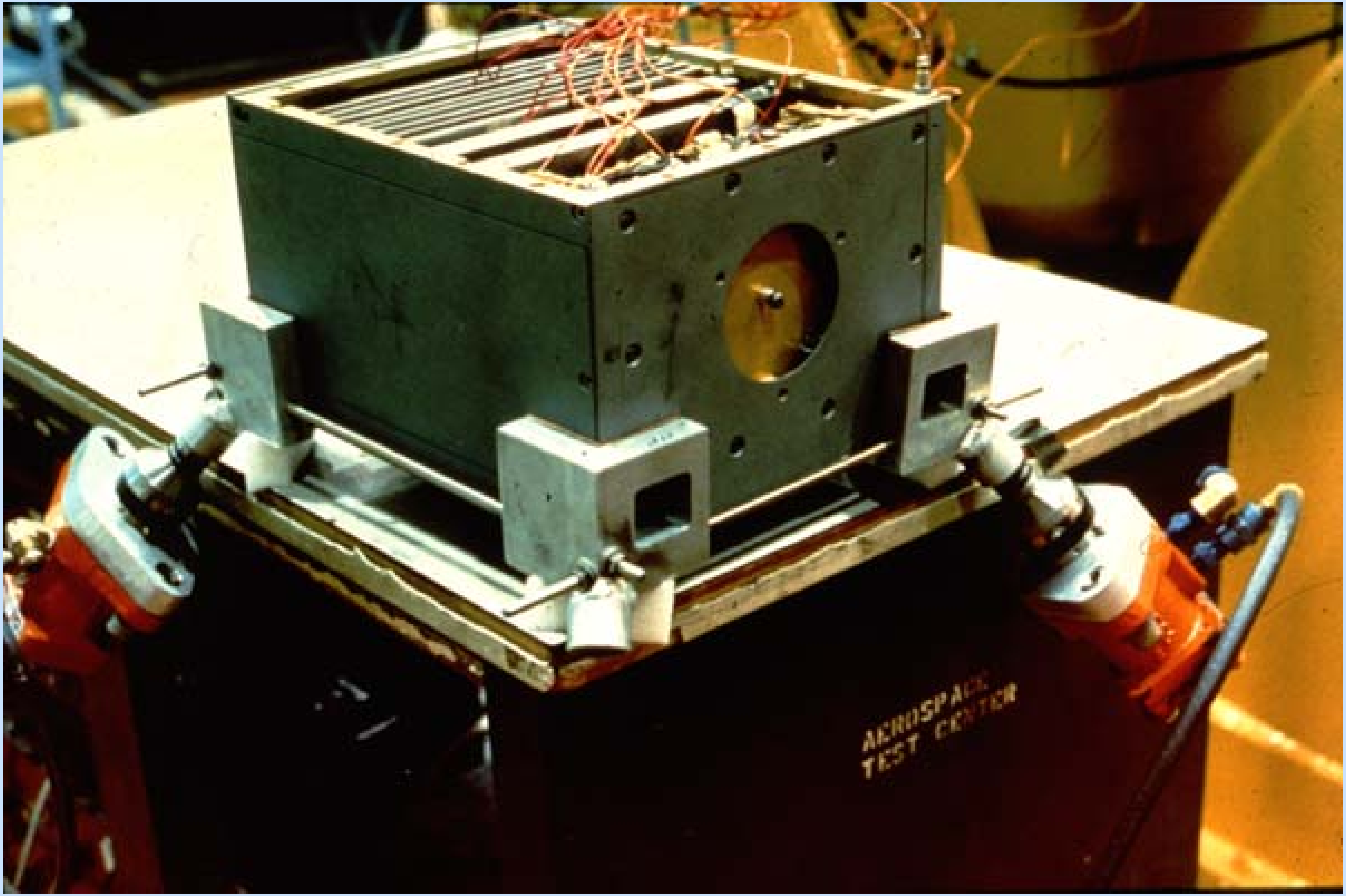


Figure 7 Two pneumatic RS units excite PWBs



In 1979 Willis J. Willoughby ordered screening to precipitate hidden defects on new “black boxes”, using random vibration and thermal cycling. Navy contractors proved that this worked. Naval system reliability climbed. The Army, Air Force and many manufacturers adopted these methods.

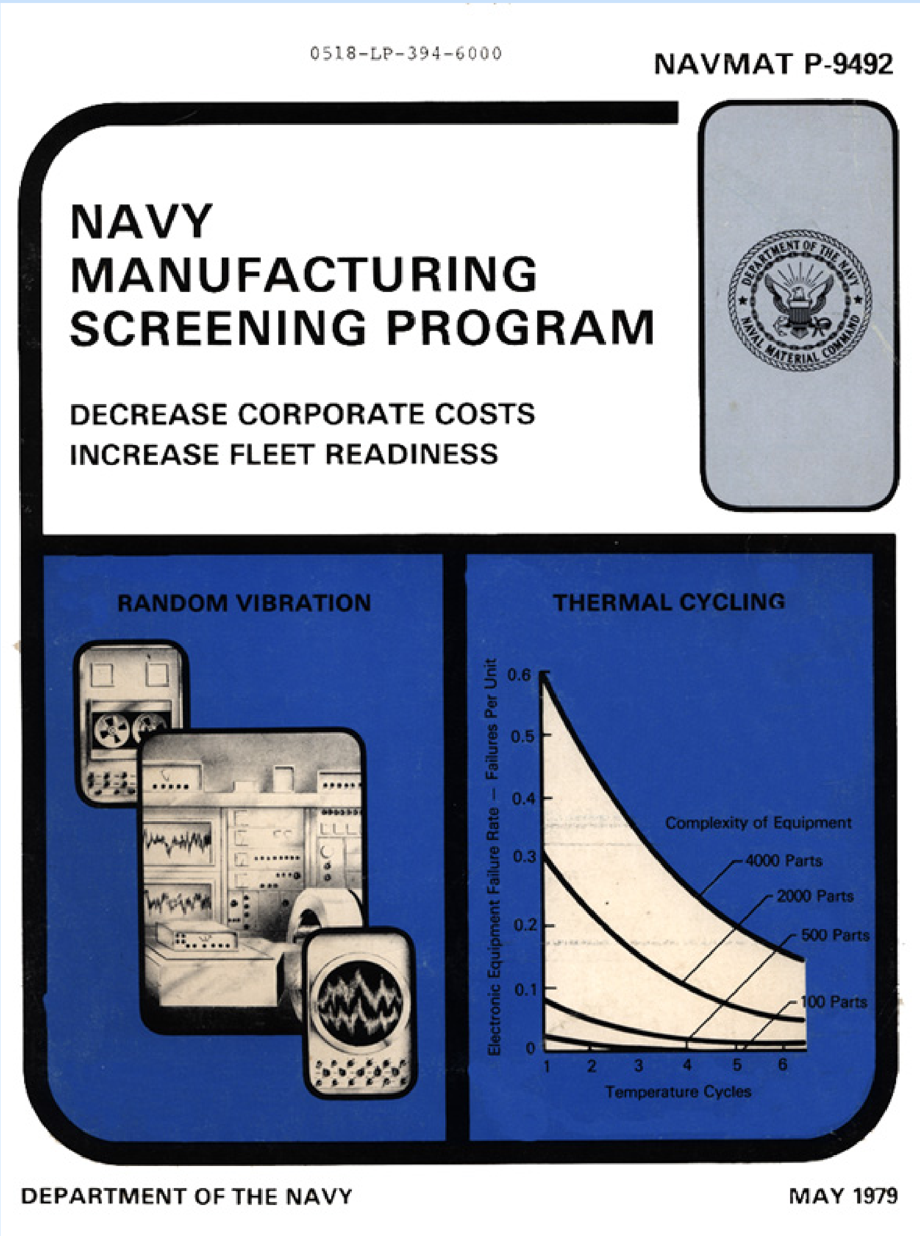


Figure 8

NAVMAT P-9492

What did Willoughby mean by “random vibration”?

He meant a kind of broad-spectrum vibration that had not been recognized prior to the “space race”.

Rocket Liftoff

ext215 rocket shuttle takeoff.avi

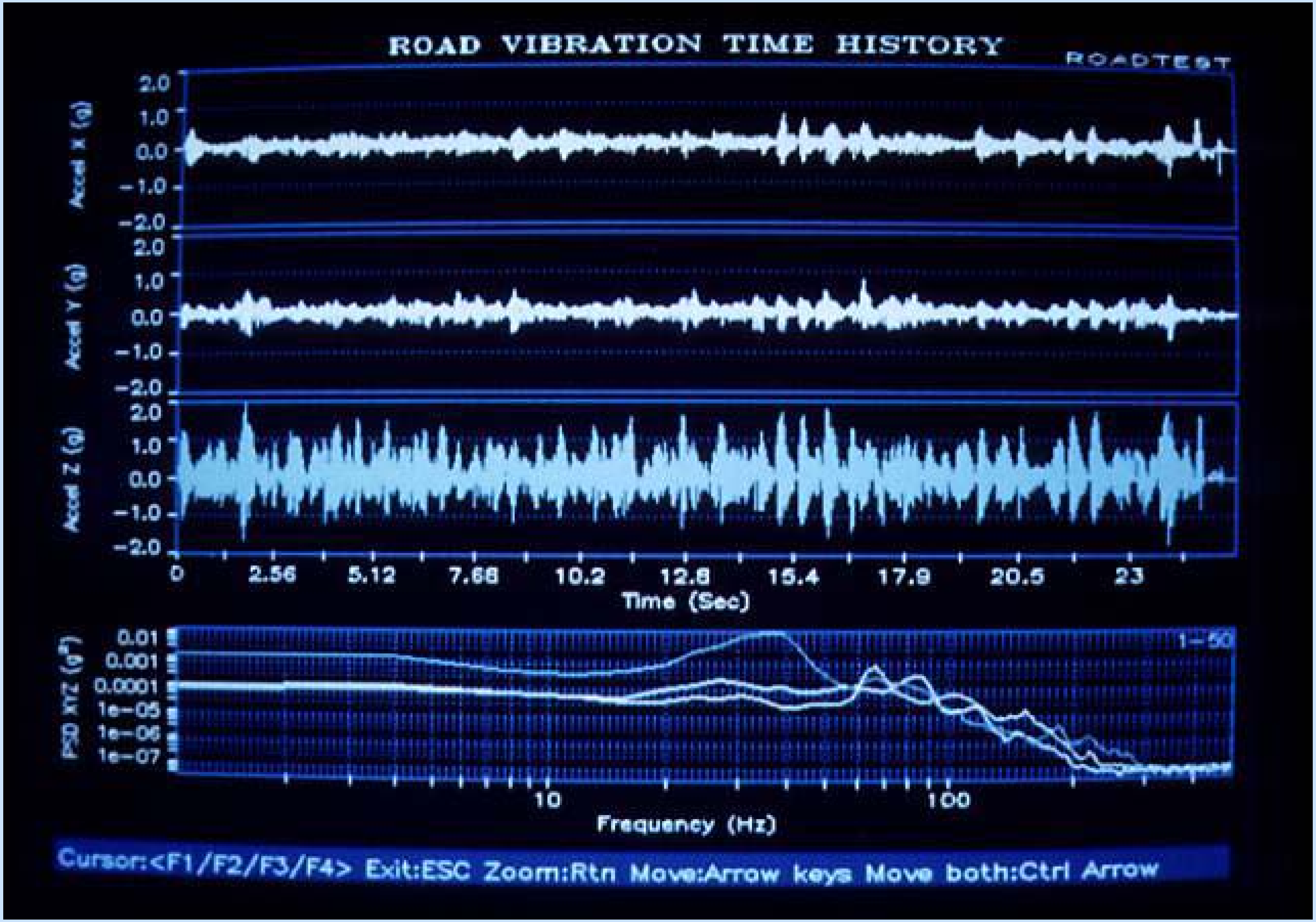
Figure 9 "Random" means unpredictable

But which, once identified, was also identified as an input to land vehicles, VC-2 and Figure 10 – discuss 3 accelerometer records, FFT and continuous spectrum.

VC-2 Detroit Street

detroit.avi

Figure 10 Analysis of automotive vibration



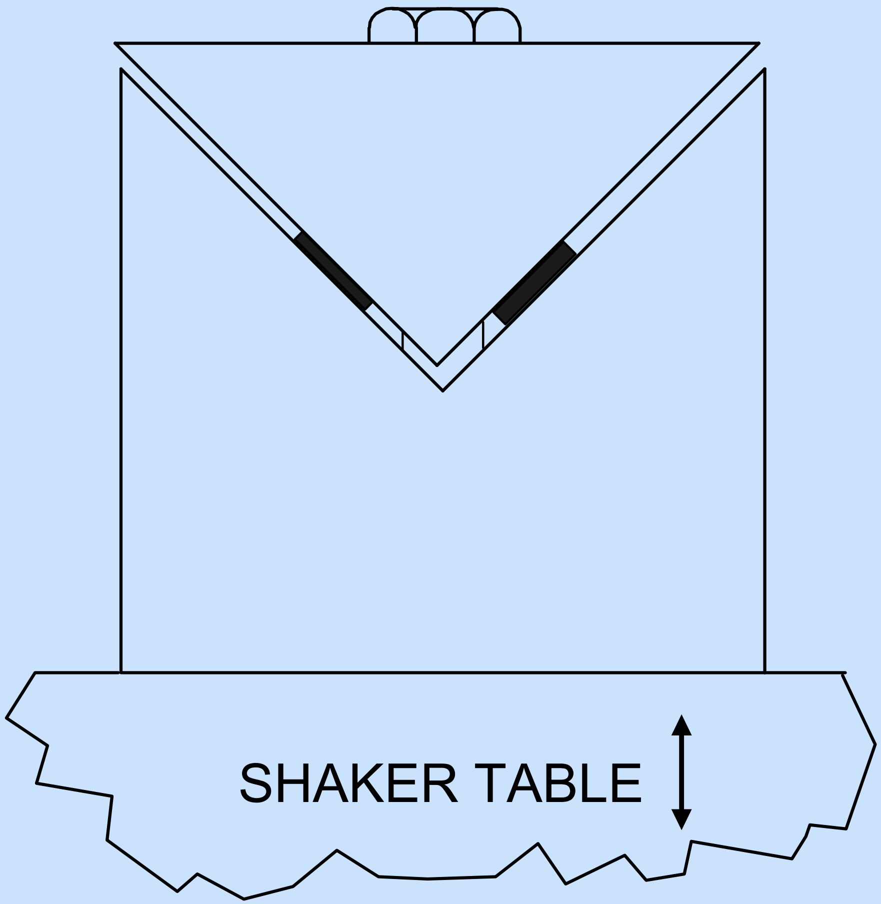
Projector off. What is the effect of random vibration on hardware?

How does the effect differ from the effect of classical one-frequency-at-a-time sine vibration?

Let’s watch what happens with both, sine first. Projector on, discuss Figure 11, narrate VC-3,4,5,6.

Figure 11

Random vibration video demonstration



Below Resonance

randem1.avi

First Resonance

VC-5

Second Resonance

randem3.avi

Simultaneous resonances

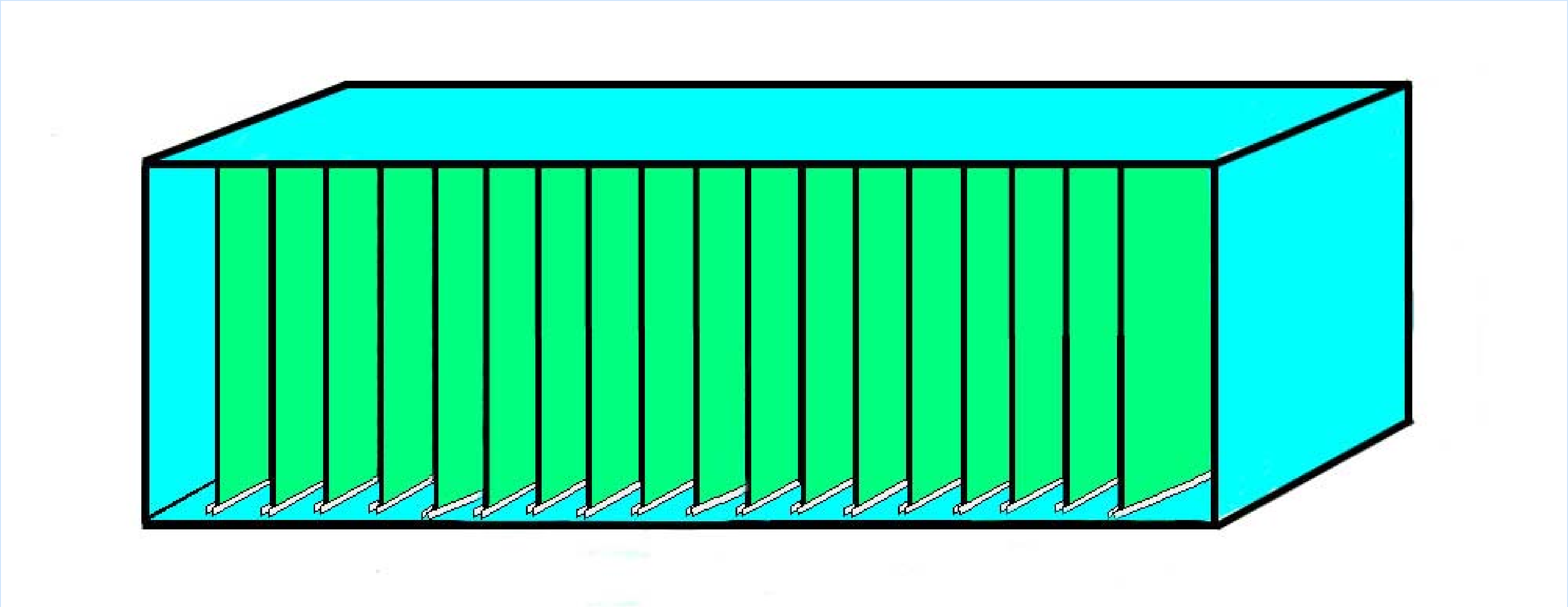
randem4.avi

What do those two reeds represent?

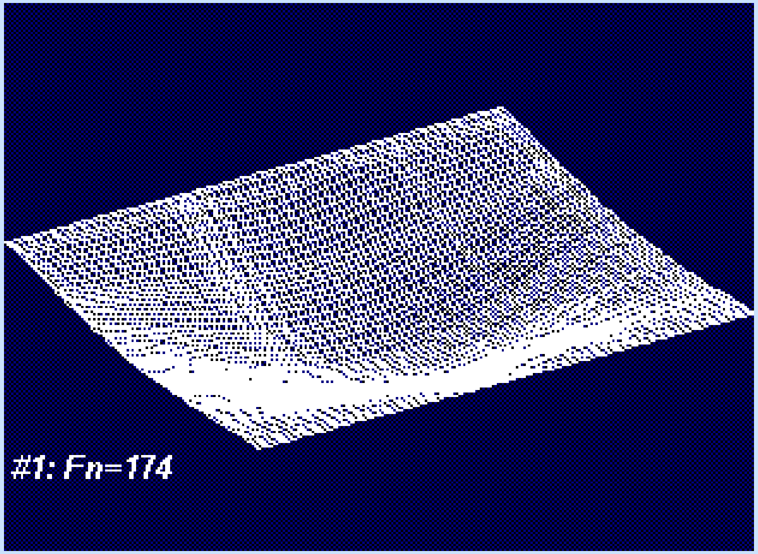
Here (Figure 12) is an example of electronic assemblies represented by the two reeds of Figure 11. These cards, differently loaded, have different resonant frequencies. If only one at a time resonates (with single-frequency sine vibration) there might be no difficulty. But if neighboring boards resonated simultaneously, they might strike.

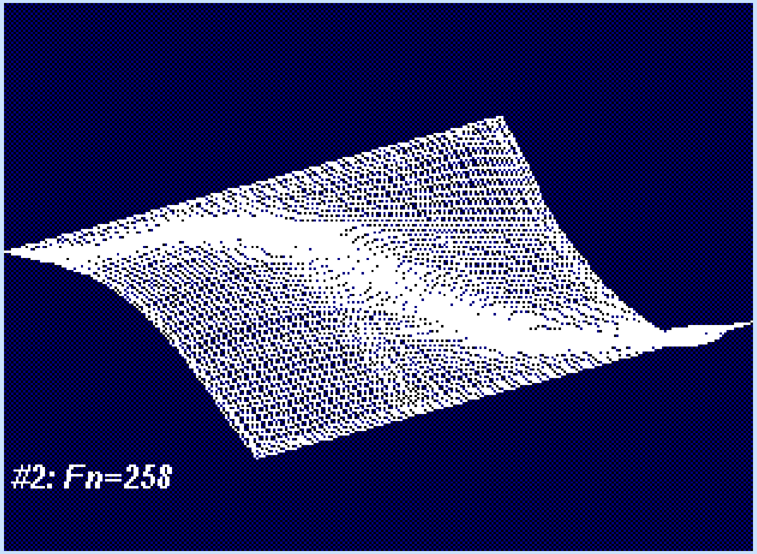
That kind of response, with large bending dynamic displacement, might only occur that the lowest frequency resonant mode at, say, 174 Hz.

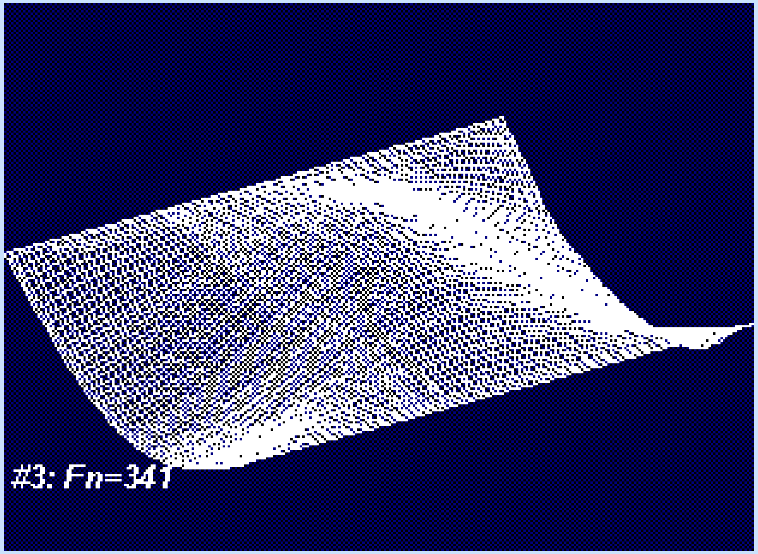
Figure 12 Card Cage with Skeleton Frame



Animation 1 Printed Wiring Board







courtesy John Starr

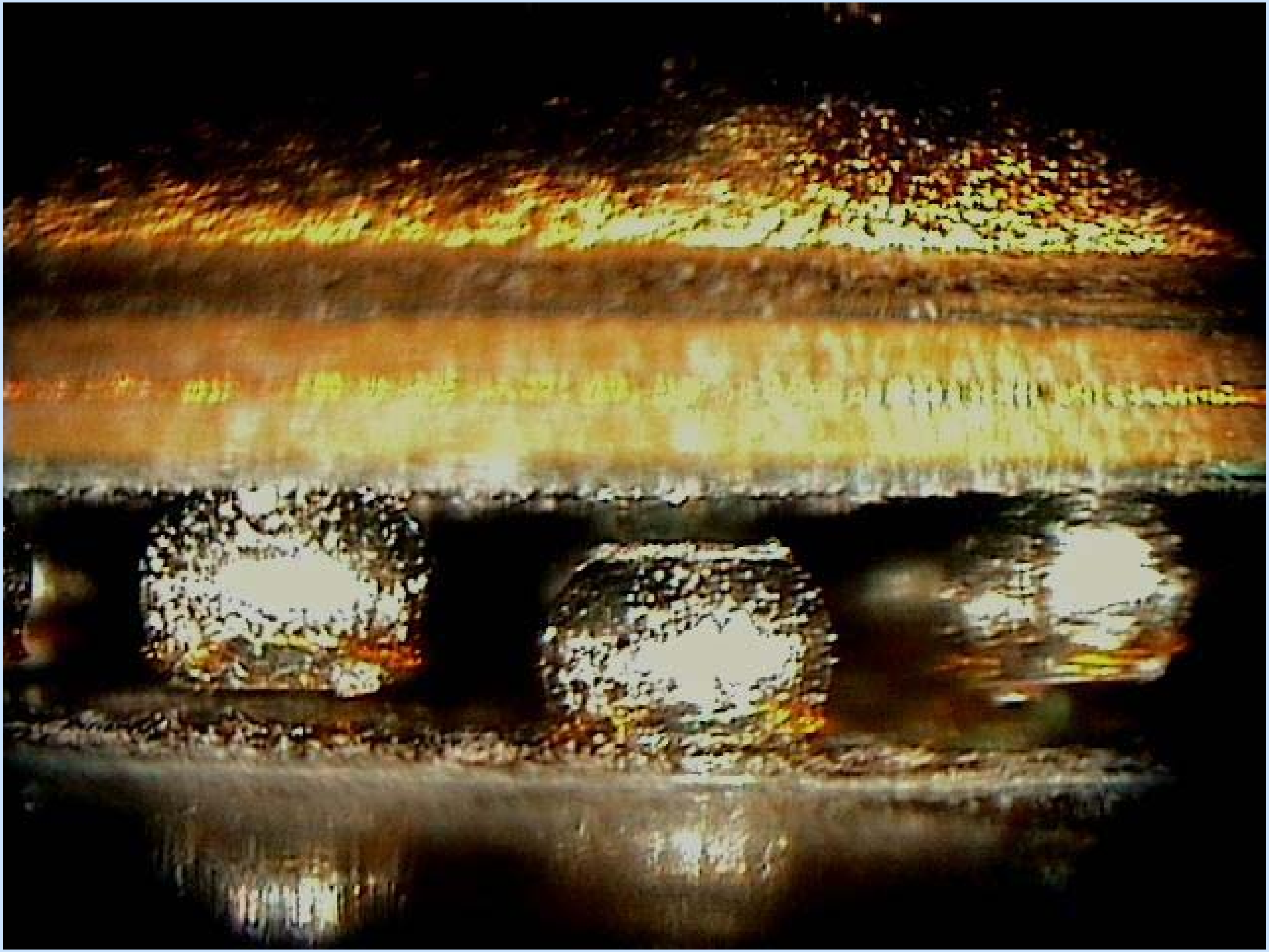
That was first mode bending. At other single frequencies, 258 and 341 Hz, the response motions are more complex.

Can you visualize the mechanical stresses on the card wiring and on the attached components?

What sort of damage might result from that rolling and twisting of a wiring card?

Figure 13

Underneath a chip



Perhaps you are saying to yourself, “Hogwash. My cards are stiff. They don’t roll and twist and bend like that.”

Please mentally magnify your 6” x 9” or 9” x 12” cards to perhaps 10’ x 15’, to the size of a trampoline. You know that a trampoline deforms.

Animation 2 Trampoline

In a test lab, how is mechanical random vibration generated for stress screening? How might that vibration be combined with thermal stressing?

Most commonly, by an electrodynamic (ED) shaker combined with a thermal chamber, Figure 14.

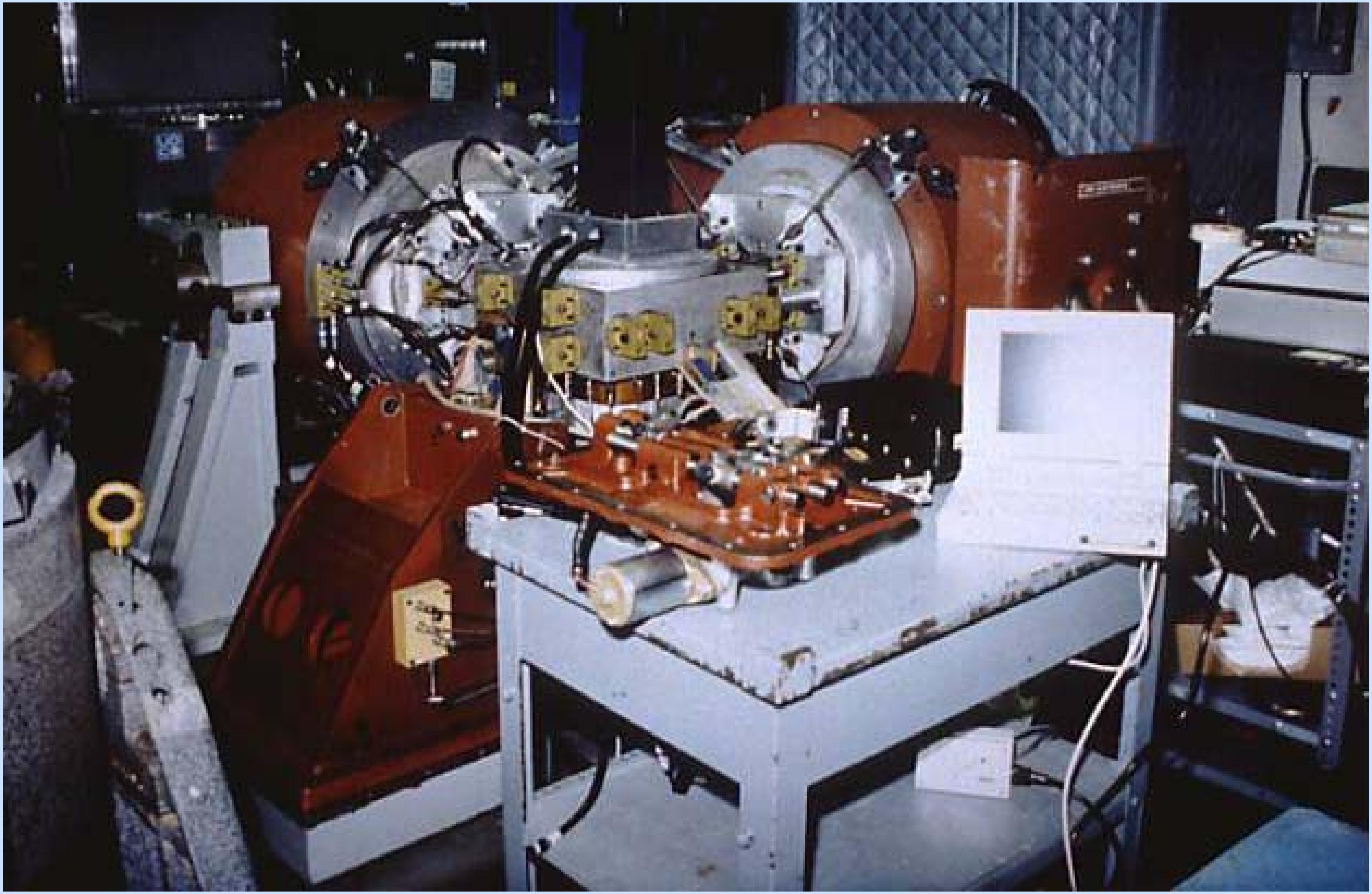
Figure 14 Combined Environment Testing

Multiple-axis random vibration is even more effective than single axis. But how to accomplish? Figures 15, 16.

Figure 15 ED Shaker + Thermal Chamber for ESS

Courtesy Santa Barbara Research Center

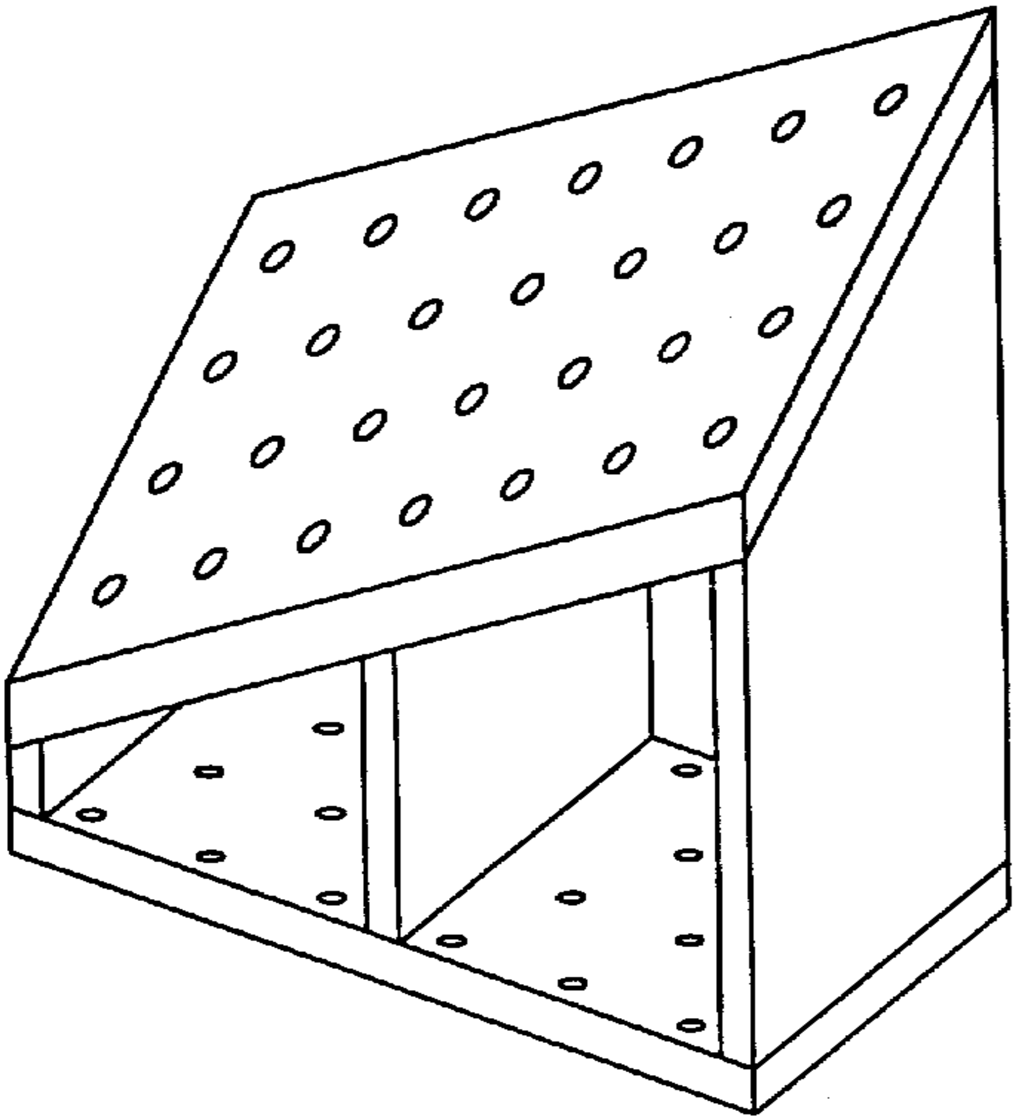
Figure 16 Three Ling ED Shakers Multi-Axis Drive Common Load at Army Research Lab, Adelphi, MD



Not only three shakers but three power amplifiers and three control channels. Very expensive and needful of much operator training.

Don’t be fooled by a claim that you can attach your DUT to a single-axis shaker via a “tilted” fixture like this. The vibration is still single-axis, even though there is a component of that vibration is each of the DUT’s axes.

Figure 17 “Tilted” Fixture does not Multi-axis Test

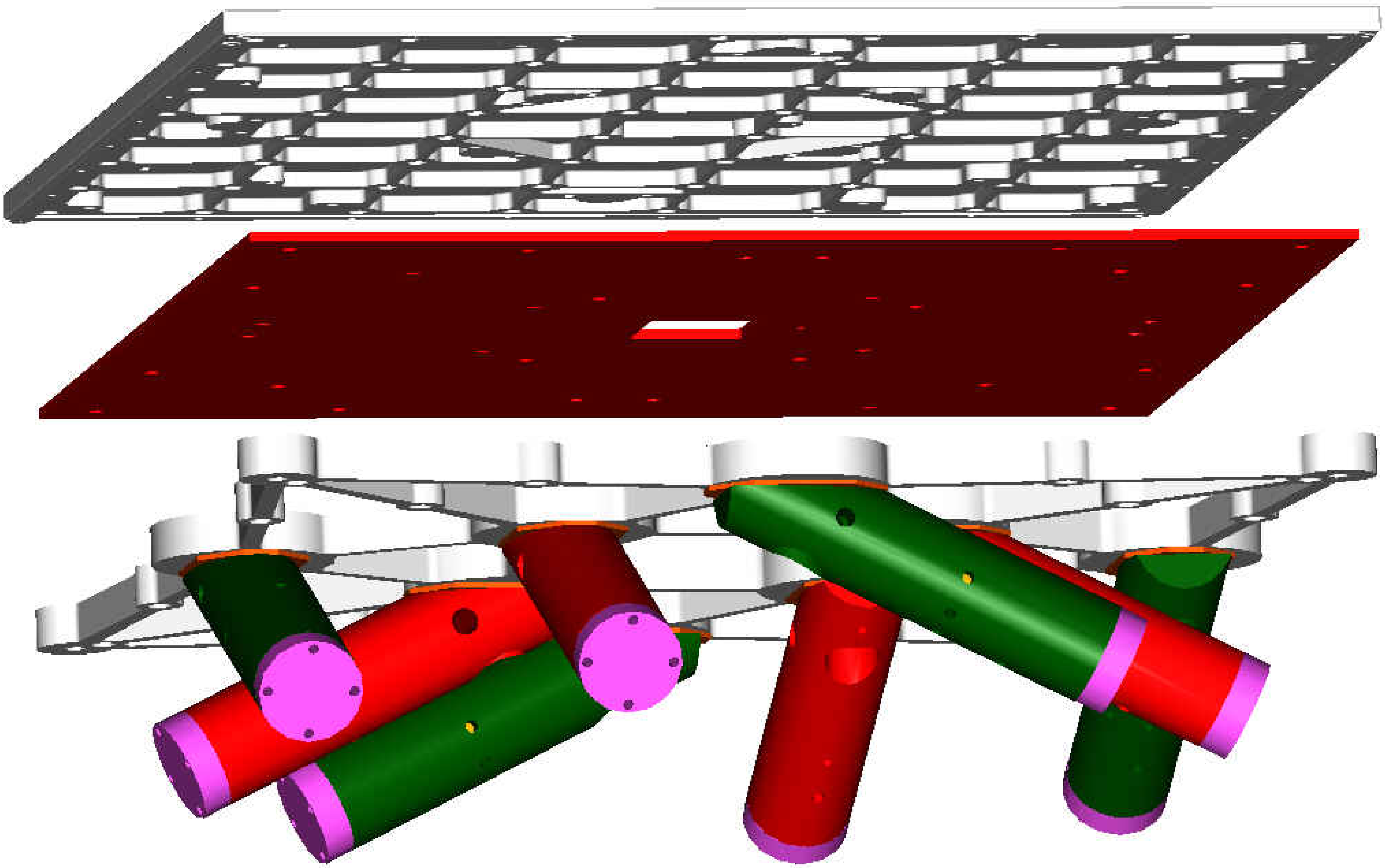


Let’s consider (Figure 18) a cheaper approach: a number of pneumatic (driven by shop air) repetitive shock (RS) machines, attached to the bottom of a softly-sprung platform.

Your hardware is attached to the top of the platform.

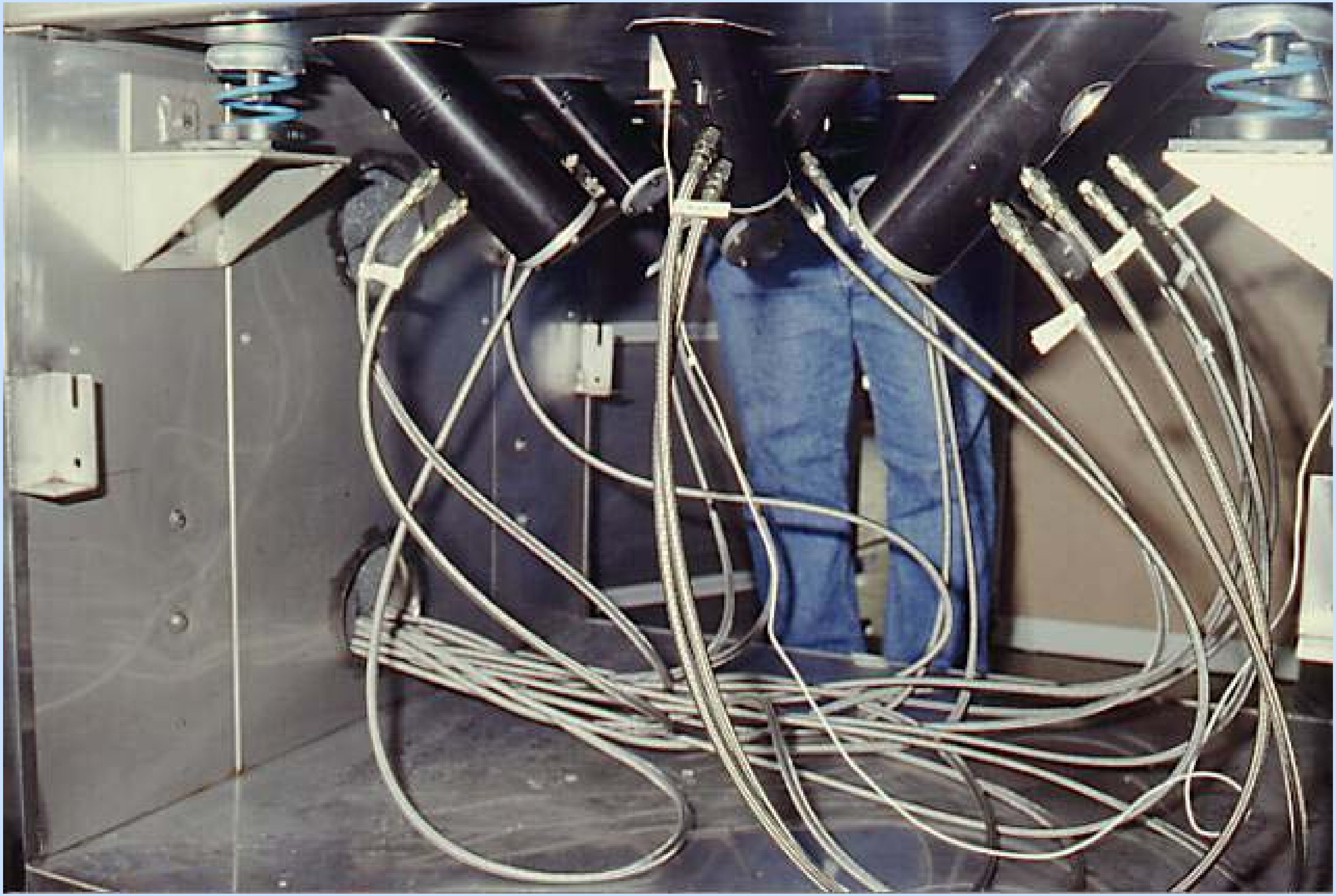
The platform is the bottom of a thermal chamber, with high velocity air, sometimes hot and sometimes cold, blasting through your hardware, alternately heating and cooling your hardware.

Figure 18 Pneumatic Vibrators drive Platform



courtesy QualMark

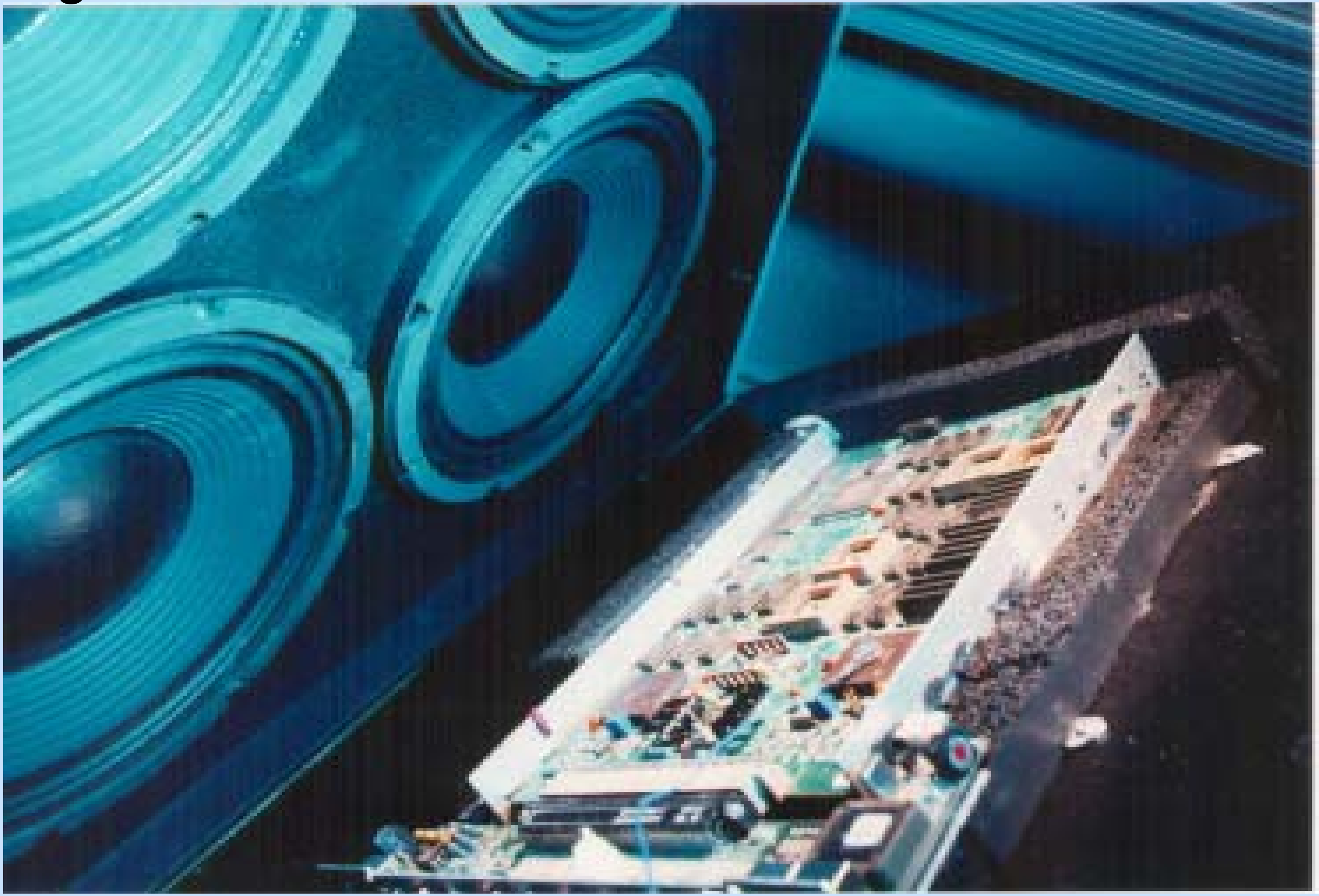
Figure 19 Pneumatic RS Units Excite Platform



courtesy GHI

Another approach: broad-spectrum intense sound, Figure 20.

Figure 20 Acoustic Excitation for Screening

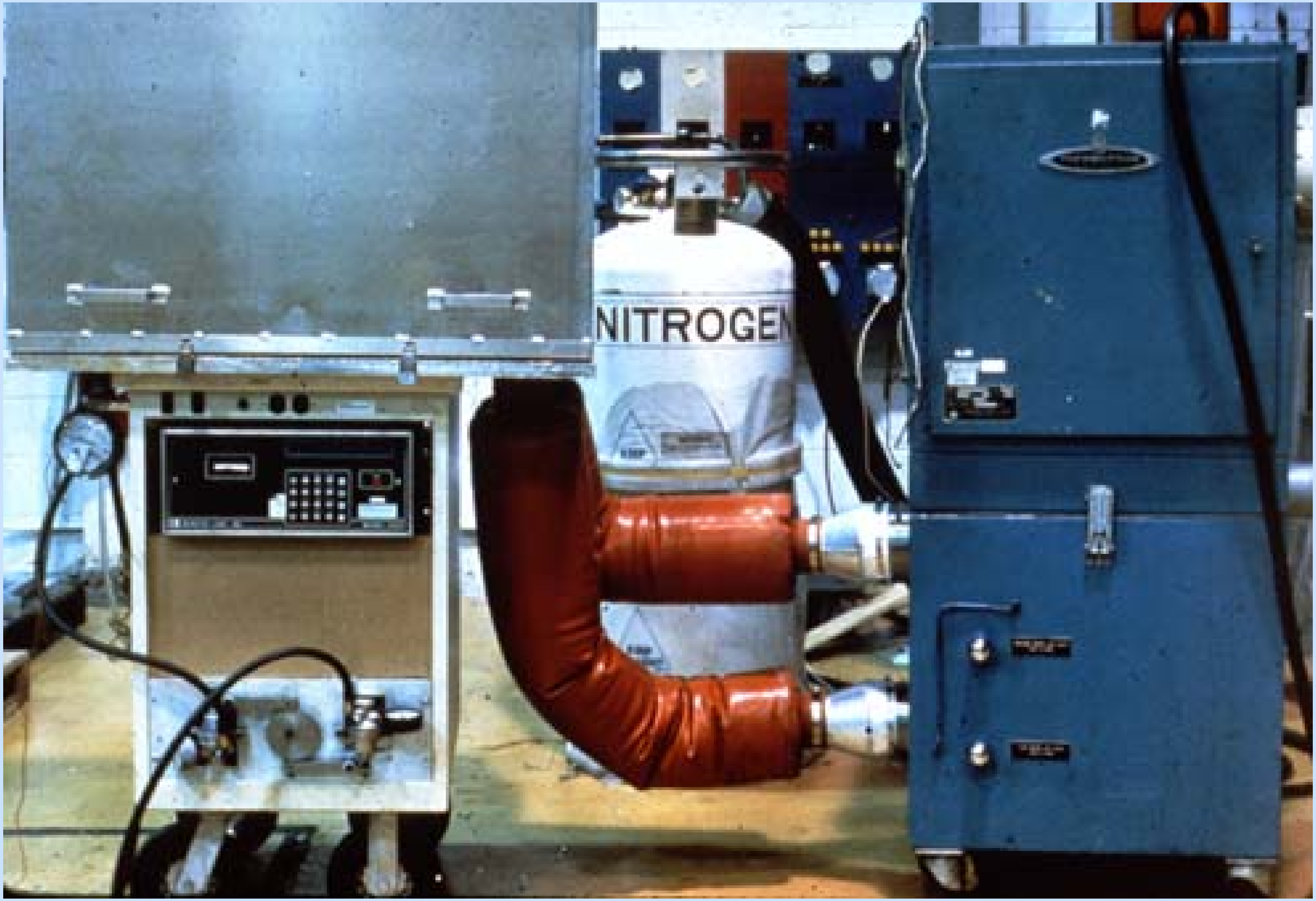


courtesy CRIQ, Montreal

These last few slides have shown stressing chambers at manufacturing facilities. But a portable system was built around 1980, Figure 21. Similar systems could be built today.

I respectfully suggest that you consider having portable thermal stressing and portable random vibration available at your test benches as tools for identifying the causes of intermittent failures in electronic black boxes.

Figure 21 Portable Stress Chamber



Thanks for listening to me.

I’d like to discuss these ideas further with you, today and tomorrow.

Today, we’ve necessarily skimmed over these ideas, especially random vibration. Might I have three days of your time, in order to present additional details?

Vibration and Shock upcoming courses

Seattle, Washington, August 12-14, 2003

Santa Barbara, California, August 26-28, 2003

Detroit, Michigan, October 8-10, 2003

Newport, Rhode Island, October 14-16

Palatine, Illinois, November 5-7

Chatsworth (Los Angeles), CA, November 19-21

Or we can bring training to your duty station.

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The foregoing is only useful if the intermittent occurs <u>in</u> the box. But many intermittents are in the cables to, from and between boxes. Those didn't get removed. Taking boxes to a repair depot, even if we manage to find some intermittents in the boxes, has little if any value.

Let's do our troubleshooting on board the aircraft, the ship or the land vehicle. Let's check the boxes, cables, displays …… all parts of the anomaly-prone system

Broken wires, faulty insulation, moisture and contamination in the cables or inside the connectors can cause intermittents. So can corrosion of the electrical contacts themselves. The RSG pelletized dry ice (CO_2) technique is also useful on connectors.

Glitches are simply not seen by these devices.

digital averaging itself is the root cause of a very large portion of these accidents! What value is it, really, to know that yet another wire caused yet another accident, when all 10,000 wires can put an aircraft at risk, and they are all aging? **The point with which the NTSB should be concerned is why these aging problems are not being detected prior to flight. Since aging implies an on-going degradation over time, why is this intermittent electro-mechanical type of degradation in the connectivity elements not detectable at test time?**

Averaging any testing data obliterates the true facts as effectively as if someone shreds documents critical to the outcome of a high-level investigation.

•Patented "PARALLOG" (Parallel/Analog), all-test-points, all-the-time, hardware neural network, is the ONLY testing technology guaranteed to be measuring the right circuit at the right time for aging/intermittent/NFF events.

•There is absolutely NO test point scanning, NO digital sampling and NO missed intermittent events.

•Methodology more closely simulates actual operational conditions than any other testing method.

- Sets a new standard for safety and reliability testing.
- Tests directly for the cause of failure, not ambiguous engineering requirements.
- Uses patented Analog Neural Network, Omnipresent Sensing technology.
- Super high sensitivity detects aging problems, even before they become dangerous failures.
- No measurement gaps on any test point at any time, guarantees results.
- Can test thousands of lines, individually, yet simultaneously and continuously.

•Tests both the conductor and the insulation* at safe (3.5 volts max) levels.

•Testing can be performed in-situ, no need to remove or disconnect attached LRUs or other devices.

•Test from a single connection point with no need for long return lines from the back of the aircraft.

•Tests wiring, controls, sensors, motors, busses, connectors, LRUs, etc.

•Technician level set-up and operation.

•Fully menu driven operation and self-learn capability.

•Full test documentation and archiving capability, and customizable for your needs.

To address these problems, the IFD-2000 Intermittent Fault Detector was designed. Based on proprietary neural network technology, the IFD-2000 can simultaneously monitor 256+ input lines for transients in the electronic impedance of the Unit Under Test (**UUT**). Because the IFD-2000 can detect transients at extremely low levels, intermittent faults are easily exposed. These faults can be repaired long before they cause a system malfunction, and without the added wear of stress testing. This type of proactive testing can dramatically improve safety and operational readiness, reduce maintenance costs, and extend the life of the system by several years.

Some mechanical stimulus of the aircraft, ship or land vehicle can assist in creating an intermittent condition.

This might be a theater-seat stimulator attached to the aircraft, ship or land vehicle structure.

1. Apply electrical power, appropriate input signals and an appropriate load.

2. Monitor and continuously record many outputs and test points. Use analog (not digital) equipment. That IFD unit we saw earlier would be very useful at your bench.

3. Apply thermal and vibration stresses. Let the IFD monitor and record.

4. Has anything changed, even briefly? Investigate. Perhaps you have triggered the intermittent condition you sought. Localize the problem. Get help if necessary.

courtesy Universal Synaptics

courtesy Universal Synaptics

courtesy Universal Synaptics

Before I finish, let me ask you a question. How do you verify that your cards are making good contact with the back plane or the mother board? I've heard that oxidized, contaminated contacts here are a major source of "intermittents". Is this true?

Do you routinely remove the cards and clean the contacts? How do you clean them?

How do you verify that your cable connectors are making good contact with your boxes? Do you routinely remove the connectors and clean the contacts? How do you clean them?

Have any of you tried the RSG technique of blasting with air-driven pelletized dry ice (CO_2)? Will you tell the others how it worked? Or will you tell me privately, later today?

Obviously, when a test fails to find an intermittent component, there is no "component" to log into the historical record and with no "component" to log-in, the failure mode encountered is not logged in either. Nothing failed, per a very narrow self-serving definition of the word "failure". The "data" that everyone is looking for is there, it is just not reported, tracked or correlated correctly.

Generally speaking, you (flight line or maintenance depot) don't have any proper tests for intermittent conditions.

Intermittency connotes two states of being, one finite or the good state, the other infinite or everything else—and that can cover a whole lot of presently untested territory.

In nearly all cases, the more accurately a meter can split a fraction of an ohm or other quantity, the slower it is likely to operate and therefore, the less likely it will be able to respond to intermittency or glitches in any meaningful way.

They and others testing critical, high priority equipment, need to realize that digital based testing equipment has a massive blind spot when testing for these aging related, randomly occurring, intermittent glitches. Only analog based technology when coupled with parallel operation, has the speed and bandwidth capability necessary to achieve the required level of confidence to tackle this testing job. Anything less is just going through the testing motions, wasting time and effort and putting the enterprise at risk.

The key to making all of this a reality is of course to first recognize that a serious problem exists. A definition of Insanity, is doing the same thing over and over and each time expecting different results. The testing philosophies of the past have put us where we are today and trying to resolve this problem once again with more digital instrument upgrades to higher accuracy is simply not going to work.

These depot descriptions and interpretations imply that a problem never existed, that the UUT was erroneously removed, that someone made a mistake or that the problem amazingly healed itself. Don't believe it. Somewhere along the line someone did encounter a problem during operation, during diagnostics or during maintenance.

Unfortunately, until recently vehicle diagnostic people have had no modern tools for analyzing modern intermittents. Nor have depot maintenance people. Faulty LRUs have been sent back to users, where they "act up" again. And again. And again.